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An Assessment of Potential Risk Resulting from a Maximum Credible Accident Scenario at the Proposed Explosive Waste Storage Facility (EWSF)

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DISCLAIMER

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1.0 INTRODUCTION

Lawrence Livermore National Laboratory (LLNL) proposes to build, permit, and operate a storage facility for explosive wastes at LLNL's Explosive Test Site, Site 300. The facility would consist of four existing magazines, four new magazettes (small concrete vaults), and a new prefabricated metal building. The existing magazines would be converted from their original use as explosive materials storage units to explosive waste storage units. The prefabricated metal building would be erected in an already-disturbed area near the four existing magazines and would provide storage for explosive-contaminated materials such as paper, wood, lab ware, and gloves. Ash from on-site treatment of explosive waste would also be stored in the prefabricated metal building prior to sampling, analysis, and shipment. The magazettes would be installed at each magazine and would provide segregated storage for explosive waste types including detonators, actuators, and other initiating devices.

The proposed facility would be used to store explosive wastes generated by the Hydrotest and Explosive Development Programs at LLNL prior to treatment on-site or shipment to permitted, commercial, off-site treatment facilities. Explosive wastes to be stored in the proposed facility represent a full spectrum of Department of Energy (DOE) and LLNL explosive wastes.

2.0 DESCRIPTION OF THE PROPOSED SCENARIO

2.1 Document Purpose

This document identifies and evaluates the risk to human health and the environment associated with the operation of the proposed EWSF. As the explosive wastes are handled and stored in sealed containers to control exposure to personnel, the routine operation of the EWSF poses no risk to human health and the environment. While the EWSF will be managed in a manner to minimize potential accidents and the probability of any accident occurring is low, the only potential for releases to the environment occur during accidents. Thus, an accident scenario was used to evaluate the risk to human health and the environment associated with the operation of the proposed EWSF.

While an accidental detonation at the EWSF is a very low probability event, it was selected for the accident scenario because accidental detonation posed the greatest potential for public risk. A fire at the EWSF would result in similar potential exposure to the products of combustion, but would not cause blast damage. Any spills at the EWSF would be contained by the facility and not result in public exposure.

2.2 Location

Site 300 is located 15 road miles southeast of the Livermore site along the San Joaquin County and Alameda County border (see Figure 1). All the proposed facilities would be located in San Joaquin County. Building 829, the existing open burning (OB) facility, is located in the southern portion of Site 300. The four magazines that would be converted to explosive waste storage magazines (M1, M2, M3, and M4) are located east of Building 829 and are served by an access road designated as Upper Magazine Loop. The proposed prefabricated metal building (designated as Building 816) would be erected between magazine M1 and magazine M4 on a level, previously disturbed site within and adjacent to Upper Magazine Loop. Figure 1 shows the general location of the EWSF and Building 829 at Site 300. The layout of the magazines and their relationship to the proposed location of Building 816 are shown in Figure 2.

Although the EWSF is located in the southern portion of Site 300, the site is about 3,600 feet north of both Corral Hollow Road and the southern Site 300 boundary.

2.3 Scenario Description

This risk assessment postulates the effects of a hypothetical accidental detonation of 5,000 pounds (2272 kg) of explosive waste contained within a single magazine at the EWSF. This scenario represents the maximum credible accident scenario for the proposed facilities. Scenarios involving more than one magazine were not considered credible, because the magazines comply with the intermagazine quantity-distance standards established by DOD[1] to prevent the propagation of an explosion from one magazine to another.

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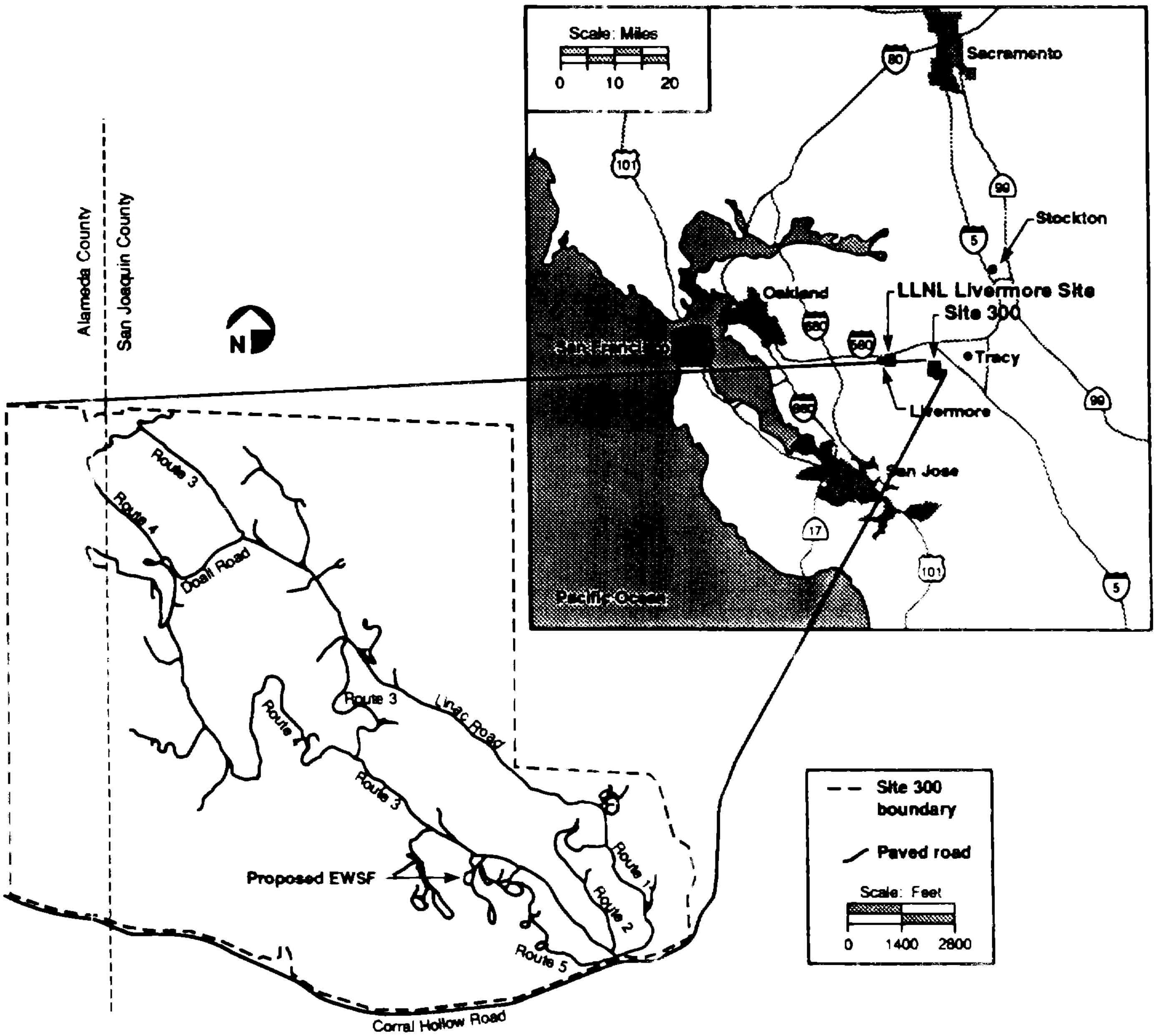
[1] DOD Ammunition and Explosives Safety Standards, July 1984, DOD 6055.9-STD, Department of Defense.



ORAD/EWSF/Fig. 1

Figure 1. Location of Site 300 and the proposed Explosive Waste Storage Facility within Site 300.

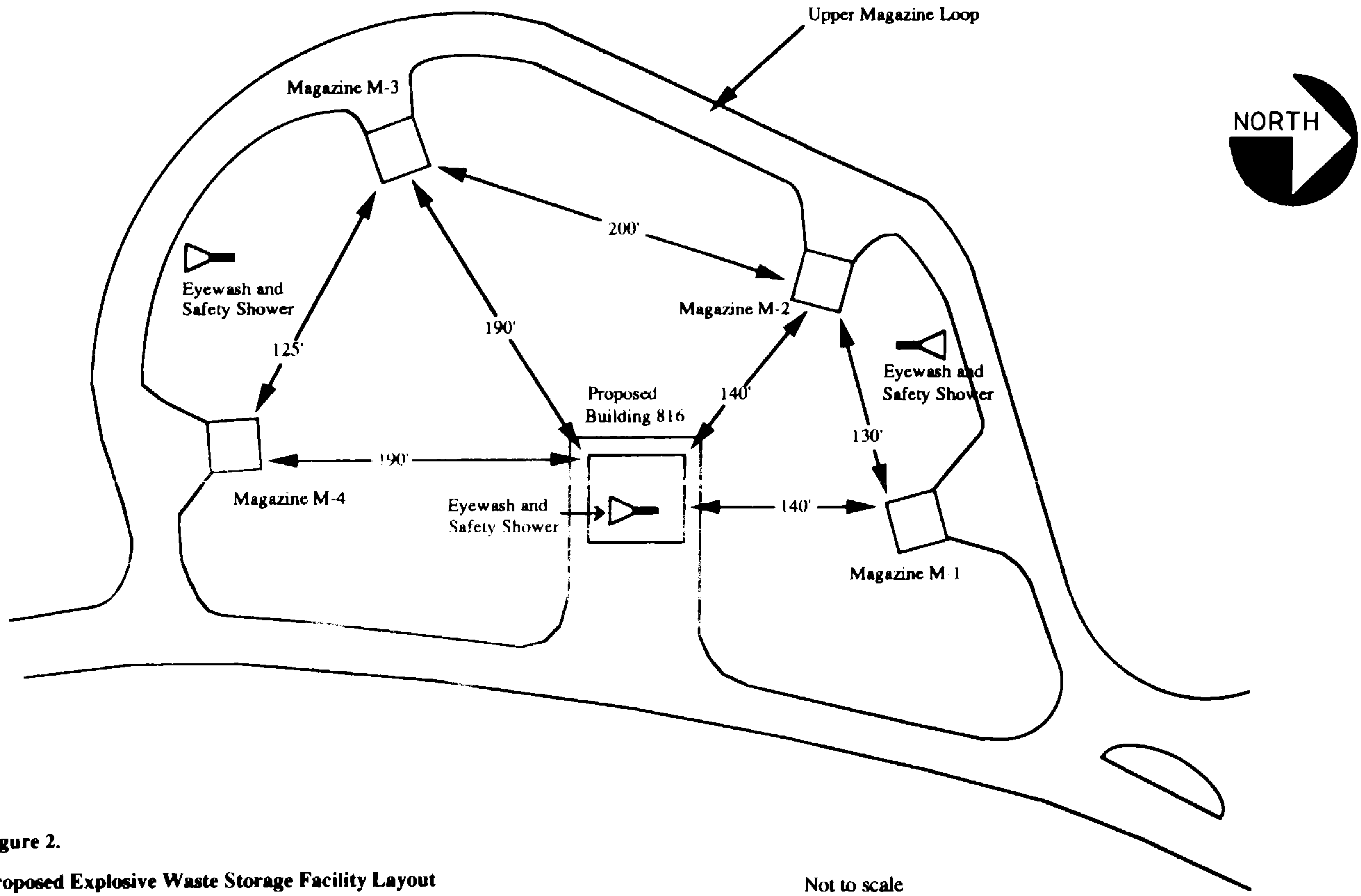


Figure 2.

Proposed Explosive Waste Storage Facility Layout
Site 300, Lawrence Livermore National Laboratory

Not to scale
All distances approximate

Records of materials processed in the existing open burning (OB) facility (B-829) were reviewed to develop a maximum credible mix of explosive types that might be stored in the largest single magazine in the proposed facilities. Also, the segregation of explosive wastes by compatibility type was considered in the development of this estimate. In Table 1 this maximum quantity is apportioned among the maximum credible explosive waste types and associated quantities that might be stored. In developing this hypothetical mix of explosives, relatively high amounts of explosive formulations with disproportionately high halogen contents were selected to create the maximum credible worst-case scenario.

Table 1. Maximum Credible Mix of Explosive Wastes and Amounts.

Explosive Waste Type	Amount (lb)	Amount (kg)
TATB	400	182
LX-17	1600	727
LX-14	800	364
PETN	100	45
HMX	100	45
LX-10	500	227
LX-04	500	227
LX-07	500	227
PBX-9404	500	227
Total	5000	2272

The accidental detonation scenario postulates two types of risks: (1) the effect of a blast to the general public (off-site personnel), and (2) the potential exposure to decomposition products (products of combustion). Based on the above conditions, the consequences are evaluated

3.0 EFFECTS OF BLAST TO GENERAL PUBLIC

The potential impact of the blast from an explosion is minimized by application of quantity-distance standards. The quantity-distance standards specify the minimum distance from an explosive operation based on acceptable levels of risk. The quantity-distance (Q/D) standards used to ensure adequate protection of the general public are the inhabited building distances.

There are two inhabited building distances established by DOD[1]. The first inhabited building distance provides protection from the effects of the blast over-pressure. The second inhabited building distance provides protection from fragments and debris generated by the initial blast. The distance between the proposed EWSF and the property line would be significantly farther than the minimum Q/D requirement and would provide an additional margin of protection. Table 2 demonstrates that the distance to the property line from the proposed EWSF substantially exceeds the DOD Q/D standards for inhabited buildings.

Table 2. Minimum Inhabited Building Distances for 5,000 Pounds Net Explosive Weight[1]

Distance to Property Line from Proposed EWSF	Inhabited Building Dist. Blast Over-Pressure	Inhabited Building Dist. Fragmentation
3,600 ft (1,097 m)	600 ft (183 m)	1,250 ft (381 m)

4.0 EXPOSURE TO DECOMPOSITION PRODUCTS

4.1 Description of Emissions

The decomposition product gases resulting from the detonation of explosives contained within a single magazine would have the potential to reach on-site and off-site receptors. The types of gases produced would, in general, depend upon the types and amounts of explosives stored in the magazine. The

[1] DOD Ammunition and Explosives Safety Standards, July 1984, DOD 6055.9-STD, Department of Defense, Washington, D.C.

maximum credible mix of explosives given in Table 1 was used as the basis for estimating the emissions of decomposition products.

The decomposition product gases produced by a detonation of the projected mix of explosives would be expected to be similar to those identified by Mader (1979)[2]: N_2, H_2, H_2O, O_2, F_2, HF, Cl_2 HCl, CO, CO_2, CH_4, HCN, NH_3, NO_2 and NO. The masses of these decomposition product gases were estimated using the amounts of explosive types listed in Table 1 and by applying the DOE TIGER Code[3]. The estimation of these masses assumed that only the air contained within the bunker would be available for combustion Additional air would result in more complete combustion of some of the carbon-containing species, but the resulting mass of gaseous HF and HCl (the decomposition product gases with the greatest health risks) would not increase since all available chlorine and fluorine are calculated to be present as HCl and HF. The estimated masses of the expected decomposition product gases are listed in Table 3

Since this evaluation is based on the accidental detonation of explosives in a magazine, no physical stack exists. For the purpose of estimating usable release parameters, the size of a typical fireball resulting from a 5,000-pound (2272-kg) explosion was estimated. Assuming that the initial volume of gaseous products is formed in a hemispherical geometry, this hemisphere would expand to a radius of approximately 40 feet (13.3 m) at 1 atmosphere The initial temperature was estimated to be 761K. The buoyancy of these very hot gases would cause the hemisphere to rise rapidly.

4.2 Estimation of Exposure Concentrations

The dispersion of decomposition product gases and the resulting concentrations at the maximally exposed on-site and off-site receptors were estimated using the EPA INPUFF model[4]. INPUFF is a non-steady-state Gaussian plume model. INPUFF was selected over standard screening level models

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2 Mader, C. L., 1979, Numerical Modeling of Detonations, University of California Press, Berkeley and Los Angeles, CA, ISBN 0-520-03655-7.

3 Cowperthwaite, M. and W. H. Zwisler, 1973, TIGER Computer Program Documentation, SRI Publication No. Z106, January 1973.

4 Petersen, W. B., J. A. Catalano, T. Chico, and T. S. Yuen, 1984, INPUFF—A Single Source Gaussian Puff Dispersion Algorithm, U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA-600/8-84-024.

because it is a "puff" model, and the event being modeled is a detonation resulting in gases released as a puff (a plume of short duration) rather than as a steady-state emission. With "puff" models, the concentration at a given point varies as a function of time due to the approach and passage of the modeled cloud. Exposure concentrations based on 1-hour time averaging were calculated.

Table 3. Masses of Decomposition Product Gases.

Decomposition Product Gas	Mass (kg)
N_2	748.07
CO_2	975.17
H_2O	34.99
CO	238.48
O_2	0.00
NO	0.00
NO_2	0.00
HF	72.54
H_2	8.55
HCl	16.71
Cl_2	0.00
NH_3	0.05
HCN	0.00
CH_4	160.74
F_2	0.00

The input parameters are given in Table 4. A range of meteorological parameters were modeled to identify the worst-case exposure level. In general, the meteorological conditions modeled were the combinations of wind speeds and stability classes used in the PTPLU model[5,6]; however, highly stable atmospheric conditions (Pasquill-Gifford classes E and F) were not modeled. Highly stable

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5 Pierce, T. E., D. B. Turner, J. A. Catalano, and F. V. Hale, 1982, "PTPLU--A Single Source Gaussian Dispersion Algorithm," U.S. Environmental Protection Agency Publication EPA-600/8-82-014.

6 Pierce, T. E., 1986, "ADDENDUM TO PTPLU-A Single Source Gaussian Dispersion Algorithm," U.S. Environmental Protection Agency Publication EPA/600/8-86/042.

atmospheric conditions form near the ground at night, and the high-temperature plume would pierce the inversion and result in a zero-calculated ground-level exposure. The receptor locations were set at between 0.5 and 40.0 km. All receptor locations were located along the center line of the cloud path. A detailed summary of the input parameters and the results are included in the Appendix.

The model determined that the maximally exposed receptor would be located approximately 1 km downwind from the proposed facilities. The nearest property line is about 1 km to the south of the proposed EWSF; therefore, the maximally exposed receptor could be located off-site.

INPUFF assumes all receptors are at the same elevation as the point of discharge and does not simulate terrain effects. Although Site 300 has complex terrain features, the EWSF will be located on a ridge about 300-500 feet higher in elevation than potential receptors at the property line on Corral Hollow Road. This causes INPUFF (and other flat terrain models) to overestimate the ground-level concentrations and, thus, provide conservative exposure estimates.

4.3 Estimation of Health Risk

This risk estimation was limited to considering acute inhalation exposure to decomposition products because none of the identified decomposition products (Table 3) require evaluation for non inhalation exposures (multiple pathway analysis) and the accident scenario is a single short-duration event that would not result in chronic exposures. Cancer burdens were not calculated because none of the identified decomposition products (Table 3) are listed as carcinogenic in the CAPCOA Risk Assessment Guidelines[7]

The CAPCOA Risk Assessment Guidelines do establish acute acceptable exposure levels (AELs) that are generally based on the most sensitive adverse health effect reported in the medical and toxicological literature. The Guidelines are designed to protect the most sensitive individuals in the population by the

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[7] California Air Pollution Control Officers Association (CAPCOA), 1992, CAPCOA Risk Assessment Guidelines, January 1992.

inclusion of "margins of safety." The specific AELs for HF and HCl are based on ambient concentration limits (ACLs) developed by Lewis and Alexeeff[8].

Table 4. INPUFF Modeling Input Parameters.

Parameter	Value	Notes
Emission rate	1,209 g/s	Corresponds to 72.54 kg of HF gas; results scale linearly with the mass of gas
Release duration	60 s	One puff
Release height	30 m	
Temperature	761K (488°C)	Initial gas cloud temperature
Initial diameter	13.3 m	Initial diameter of the gas cloud
Vertical velocity	1.855 m/s	Initial velocity of the gas cloud
Sigma (y and z)	10 m	
Mixing height	1000 m	
Stability class	Variable (A-D)	Pasquill-Gifford
Ambient air temperature	293K (20°C)	
Wind speed	Variable	

In addition, the American Industrial Hygiene Association (AIHA) has established Emergency Response Planning Guideline (ERPG) values that provide estimates of concentration ranges of specific substances, below which certain adverse health effects would not be expected as a consequence of acute exposure[9,10]. The following are the definitions for the ERPG-1, ERPG-2, and ERPG-3 values.

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8 Lewis, D. C. and G. V. Alexeeff, 1989, "Quantitative Risk Assessment of Non-Cancer Health Effects for Acute Exposure to Air Pollutants" *in* Proceedings of the Air and Waste Management Association 82nd Annual Meeting, June 1989, Vol. 89-91.4.

9 American Industrial Hygiene Association, 1989, Hydrogen Chloride, Emergency Response Planning Guidelines Series, Set 3, prepared by the American Industrial Hygiene Association Emergency Response Planning Committee, American Industrial Hygiene Association, Akron, OH.

10 American Industrial Hygiene Association, 1989, Hydrogen Fluoride, Emergency Response Planning Guidelines Series, Set 2, prepared by the American Industrial Hygiene Association Emergency Response Planning Committee, American Industrial Hygiene Association, Akron, OH.

ERPG-1: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing mild transient adverse health effects other than perceiving a clearly defined objectionable odor.

ERPG-2: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

ERPG-3: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

Of the decomposition product gases listed in Table 3, HF and HCl have the potential of causing the greatest hazard. The projected 1-hour average concentrations of HF and HCl result from the detonation of the maximum amount of a reasonably foreseeable worst-case mixture of explosive waste under a range of atmospheric conditions. The worst-case meteorology was determined by comparing the resulting predictions of downwind exposures. The highest predicted exposure occurred with stability class C and a 13 meter/second (29 mph) wind speed, and the maximally exposed receptor was located 1 km downwind. The maximum predicted downwind concentrations of HF and HCl are listed in Table 5. The ERPG levels established by the AIHA and the AEL established by CAPCOA for these decomposition product gases are also included in Table 5.

Table 5. Maximum Downwind Concentrations of Gaseous HF and HCl and ERPG Limits (mg/m³).

Decomposition Product Gas	Maximum 1-hr Average Concentration	Acceptable Exposure Levels	ERPG-1	ERPG-2	ERPG-3
HF	2.29E-02	0.58	4.09	16.37	40.91
HCl	5.27E-03	3.0	4.47	29.82	149.12

As shown in Table 5, the reasonably foreseeable accident scenario for the proposed facility would result in exposure of the maximally exposed receptors to concentrations of decomposition product gases more than an order of magnitude below the CAPCOA AELs and more than two orders of magnitude below ERPG-1 levels. Both AELs and the ERPG-1 limits were established for the protection of the most sensitive individuals in the population, however, the AELs are slightly more conservative.

The combined acute health effect of HF and HCl is evaluated based on the assumption that the combined effects are additive, rather than either synergistic or antagonistic. A health index is determined by dividing the predicted average concentration by the standard for each contaminant of concern to normalize the concentrations. The health indices for each contaminant are totaled to form a combined health index.

Table 6. Compliance with Combined Health Effect Standards for the Predicted Potential Exposure

Standard	Health Index HF	Health Index HCl	Combined Health Index
AEL	0.0395	0.0018	0.0413
ERPG-1	0.0056	0.0012	0.0068
ERPG-2	0.0014	0.0002	0.0016
ERPG-3	0.00056	0.00004	0.00060

Since the combined health indices are significantly less than one for the identified standards, the modeled exposure would not result in adverse health effects.

5.0 CONCLUSION

The operation of the proposed Explosive Waste Storage Facility (EWSF) will not result in unacceptable risks to human health and the environment. The potential for exposure outside of the facility does not exist from the normal operation of the EWSF, as the explosive wastes are handled only in sealed containers. The probability of a major accident at the EWSF is remote and, if it were to occur, the maximum credible accident will not result in significant adverse risk to human health and the environment.

The maximum credible accident is the accidental detonation of 5,000 pounds (2,272 kg) of waste explosives in a single magazine. The EWSF is situated such that the public risk from the effects of resulting blast and shrapnel are adequately mitigated. The exposure to decomposition products was also evaluated, and the maximum predicted exposure was significantly less than standards established to protect the most sensitive individuals in the population.

APPENDIX

Results of INPUFF Code Parameter Study for the Site 300 Explosive Waste Storage Facility

Robert Harrach and Robert Berger

Parameter Values for the Problem

Emission rate = 1,209 g/s (corresponds to 72.54 kg of HF gas being produced in the given explosion; results scale linearly with the mass of gas)

Release duration = 60 sec (one puff)

Release height = 30 m

Temperature of gas cloud = 761K

Initial diameter of gas cloud = 13.3 m

Vertical velocity of gas cloud = 1.855 m/s

Initial sigmas (y and z) characterizing the cloud = 10 m

Mixing height of the atmosphere = 1000 m

Atmospheric stability (Pasquill-Gifford) class = (variables A-D)

Ambient air temperature = 293K

Wind speed = (variable)

Table A-1. Summary of results on maximum timeaverage values of HF gas concentration for the 72.54 kg, 761K INPUFF runs.

Run Description (stability factor and wind speed in m/s)*	Max. 1-min. Average Conc. ($\mu g/m^3$)	Max. 1-hr Average Conc. ($\mu g/m^3$)	Receptor Distance (km)
A 1.6	108	13.0	1.
A 3.	232	8.8	1.
C 7.	231	5.7	3.
C 12.	823	13.7	1.
C 13.	1,376	22.9	1.
C 14.	1,343	22.4	1.
D 14.	515	8.6	5.
C 16.	480	8.0	1.
C21	418	7.0	3.

* Wind speeds lower than about 1.6 m/s result in penetration of the 1000-ft-high inversion layer by the rising cloud of hot explosion decomposition products yielding zero concentrations at ground level.

Table A-2. Spatial variation of the one-hour-average concentration of HF gas for the "worst case" scenario of all those considered (problem C 13).

The hot (761K) cloud of decomposition products from the explosion rises to a height of about 140 km and disperses as it is carried downwind. The ground-level HF-gas concentration rises from near zero to its maximum value of 22.9 $\mu g/m^3$ at a downwind distance of 1 km. The tabular entries for 2.05 km and beyond give the monotonically declining peak concentrations of the secondary, tertiary, etc., maxima produced as the cloud slowly oscillates vertically as it moves horizontally through the atmosphere-- i.e., they define the envelope bounding the downwind concentrations from about 2 km to 40 km.

Receptor Distance from Source (km)	One-Hour Average Concentration ($\mu g/m^3$)
0.50	0.00056
0.65	0.11
0.80	3.61
0.90	13.6
0.95	19.5
1.00	22.9
1.05	22.1
2.05	16.0
3.05	7.65
4.1	4.35
5.5	2.43
7.0	1.63
8.0	1.34
9.0	1.12
10.	0.95
15.	0.52
20.	0.47
30.	0.45
40.	0.44

Table A-3. Spatial variation of the maximum 1-hour average concentration of HF gas for the scenarios considered.

Calculations cover the time period up to 1 hour following the explosive release of HF gas. Blank entries in the Table indicate that a 1-hour average was not established by the time the calculation was terminated.

Receptor Distance (km)	Maximum One-Hour Average Concentration ($\mu g/m^3$)								
	A1.6	A3	C7	C12	C13	C14	D14	C16	C21
0.50	0.26	2.05	0.	0.002	0.	0.	0.	0.	0.
1.00	6.96	8.79	0.64	13.7	22.9	22.4	0.21	7.99	0.00
2.00	13.0	6.05	3.51	13.5	15.6	10.9	0.28	2.06	1.39
3.00	9.93	4.66	5.66	7.31	7.58	4.73	0.19	1.73	6.96
4.00	7.81	4.01	4.80	4.46	4.20	2.79	5.14	3.85	0.81
5.00	7.57	3.66	3.96	3.06	2.76	2.30	8.61	2.82	2.63
6.00	7.08	3.45	3.25	2.27	2.06	1.94	5.68	1.73	1.28
7.00		3.33	2.70	1.78	1.63	1.57	3.11	1.31	0.10
8.00		3.25	2.28	1.44	1.34	1.27	2.57	1.12	0.94
9.00		3.20	1.96	1.20	1.12	1.05	2.88	0.93	0.67
10.0		3.17	1.71	1.03	0.95	0.88	2.83	0.78	0.62
15.0			1.03	0.56	0.52	0.48	1.63	0.42	0.33
20.0			0.90	0.50	0.47	0.44	1.17	0.39	0.30
30.0			0.87	0.49	0.45	0.05	0.78	0.38	0.29
40.0				0.47	0.44	0.05	0.60	0.37	0.29